

Change claims 1, 10, 19 and 28 -- and add new claims 33 through 72 -- all to read as indicated below.

1 1. (amended) An imaging system for forming an image of a  
2 section of a turbid medium together with objects therein, said  
3 system comprising:

4 laser means for projecting [generating] a pulse beam  
5 [substantially uniform in intensity] to illuminate a thin  
6 segment [slice] of such [said] turbid medium;

A 7 a streak tube, having a [wide but usable] cathode, for  
8 generating a two-dimensional optical signal;

9 a field-limiting slit disposed in front of said cathode  
10 for rejecting multiply reflected light;

11 optical means disposed in front of said field-limiting  
12 slit for imaging a reflected portion of said pulse beam on  
13 said field-limiting slit;

14 two-dimensional detector means operatively connected to  
15 said streak tube for detecting said two-dimensional signal;  
16 and

17 means for generating a volume display of said medium  
18 utilizing all, or substantially all, of the reflected portion  
19 of said pulse beam; and

20 a diamond-arrangement mirror beam inverter that uses the  
21 Gaussian beam-shape properties of the pulse beam to enhance  
22 outer portions of the pulse beam.

2.  
~~10.~~

(amended) A method for detecting a target in a turbid medium, said method comprising the steps of:

generating a pulse beam [substantially uniform in intensity] and illuminating a thin slice of such [said] turbid medium utilizing the [said] pulse beam, including utilizing a diamond-arrangement mirror beam inverter that uses the Gaussian beam-shape properties of the pulse beam to enhance outer portions of the pulse beam;

generating a two-dimensional signal with a streak tube having a cathode;

rejecting multiply reflected light utilizing a field-limiting slit disposed in front of the [said] cathode;

imaging a reflected portion of the [said] pulse beam on the [said] field-limiting slit utilizing a light-collecting optical means disposed in front of the [said] field-limiting slit;

detecting the [said] two-dimensional signal generated by the [said] streak tube utilizing a two-dimensional detector operatively connected to the [said] streak tube; and

generating a volume display of the [said] medium utilizing all, or substantially all, of the reflected portion of the [said] pulse beam.

3.  
~~12~~ (amended) A system for detecting a target in a turbid medium, comprising:

source means for generating a series of narrow, fan-shaped, pulse beams [substantially uniform in intensity] to illuminate sections of the [said] turbid medium;

a streak tube comprising:

a [very wide and narrow] photocathode for collecting [the maximum amount of] reflected portions of the [said] pulse beam and in response thereto emitting a corresponding flow of [for converting said reflected portions to] photoelectrons;

a pair of deflection electrodes for generating a deflection electric field, the [said] deflection electrodes being adapted to deflect the [said] photoelectrons emitted from said photocathode; and

a phosphor layer for receiving the [said] deflected photoelectrons and in response thereto emitting a corresponding flow of [converting said deflected photoelectrons to] photons; and

means for applying a varying voltage to the [said] deflection electrodes to cause the [said]

23 photoelectrons from the [said] photocathode to move  
24 rapidly across the [said] phosphor layer, thus  
25 converting a temporal variation in the input signal  
26 into a spatial variation at the phosphor to create a  
27 two-dimensional signal utilizing all, or substan-  
28 tially all, of the reflected portions at the [said]  
29 phosphor layer;

30  
31 detector means operatively connected to the [said]  
32 phosphor layer for detecting the [said] two-dimensional  
33 signal; [and]

34 a field-limiting slit for removing multiply scattered  
35 light;

36 optical means for collecting and imaging the reflected  
37 portions on the [said] field-limiting slit; [and]

38 means for generating a volume display of the [said]  
39 turbid medium in depth utilizing all, or substantially all, of  
40 the reflected portions of the [said] pulse beam; and

41 a diamond-arrangement mirror beam inverter that uses the  
42 Gaussian beam-shape properties of the pulse beam to enhance  
43 the outer portions of the pulse beam.

1 4. ~~28~~ (amended) An [The] imaging system for detecting a target  
2 in a turbid medium, [claimed in claim 19, further] comprising:  
3 source means for generating a series of narrow, fan-  
4 shaped, pulse beams to illuminate sections of the turbid  
5 medium;

6 a streak tube comprising:

7 a photocathode for collecting reflected por-  
8 tions of the pulse beam and in response thereto  
9 emitting a corresponding flow of photoelectrons;

10 a pair of deflection electrodes for generating  
11 a deflection electric field, the deflection elec-  
12 trodes being adapted to deflect the photoelectrons  
13 emitted from said photocathode; and

14 a phosphor layer for receiving the deflected  
15 photoelectrons and in response thereto emitting a  
16 corresponding flow of photons; and

17 means for applying a varying voltage to the  
18 deflection electrodes to cause the photoelectrons  
19 from the photocathode to move rapidly across the  
20 phosphor layer, thus converting a temporal variation  
21 in the input signal into a spatial variation at the  
22 phosphor to create a two-dimensional signal utiliz-  
23

24 ing all, or substantially all, of the reflected  
25 portions at the phosphor layer;

26

AY 27 detector means operatively connected to the phosphor  
28 layer for detecting the two-dimensional signal;

29 a field-limiting slit for removing multiply scattered  
30 light;

31 optical means for collecting and imaging the reflected  
32 portions on the field-limiting slit;

33 means for generating a volume display of the turbid  
34 medium in depth utilizing all, or substantially all, of the  
35 reflected portion of the pulse beam;

36 a second photocathode for receiving [converting] photons  
37 emitted from the [said] phosphor and in response thereto  
38 emitting a corresponding flow of photoelectrons; and

39 a microchannel plate intensifier for increasing the gain  
40 of photoelectrons emitted from the [said] second photocathode;  
41 and

42 a second phosphor layer for receiving [converting]  
43 photoelectrons emitted from the [said] microchannel plate  
44 intensifier and in response thereto emitting a corresponding  
45 flow of photons, wherein the [said] second phosphor is coupled  
46 to the [said] detector means.

SUB B)

33. An imaging system for forming an image of a thin section of a turbid medium with objects therein, said system comprising:

means for projecting a pulsed thin-fan-shaped beam to selectively illuminate, along an illumination-propagation direction, a thin section of such turbid medium;

a streak tube, having a cathode for receiving reflected light back, approximately along the illumination-propagation direction, from the thin section of turbid medium; said streak tube also having an anode end, and comprising:

first electronic means for forming at the anode end of the streak tube successive thin-strip-shaped electronic-image segments of the light successively received on the cathode from the illuminated turbid-medium thin section, and

second electronic means for distributing the successive thin-strip-shaped electronic-image segments, along a direction generally perpendicular to a long dimension of the image segments, across the anode end of the streak tube,

said distributing of the electronic-image segments being in accordance with elapsed time after operation of

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26 the beam-projecting means so that each thin-strip-shaped  
27 electronic-image segment is displaced from a side of the  
28 anode end of the tube substantially in proportion to  
29 total propagation distance and time into and out from the  
30 turbid-medium thin section, to form a composite elec-  
31 tronic image of the turbid-medium thin section as a func-  
32 tion of propagation depth.



6. ~~34.~~ The imaging system of claim ~~33~~<sup>5</sup>, wherein:

the beam penetrates the thin section during a first range of times corresponding to beam propagation depth into the thin section;

15  
112 Cont. the cathode receives the reflected light during a second range of times corresponding to total propagation distances into and out from the thin section approximately along the illumination-propagation direction; said second range of times being substantially equal to propagation times within the thin section plus a substantially fixed delay substantially related to propagation times to and from the thin section;

said first electronic means forming the electronic-image segments at particular times corresponding to the particular total propagation distances for particular penetration depths; and

said second electronic means distributing the electronic-image segments in accordance with the second range of times corresponding to total propagation distances into and out from the thin section.

7. ~~35.~~ The imaging system of claim ~~33~~<sup>5</sup>, further comprising:

electrooptical means for receiving the electronic-image segments and in response producing corresponding optical-image segments to display a composite optical image.

SUBB3

1 36. An imaging system for forming an image of a thin sec-  
2 tion of a turbid medium with objects therein, said system  
3 comprising:

4 means for projecting a pulsed thin-fan-shaped beam to  
5 selectively illuminate, along an illumination-propagation  
6 direction, a thin section of such turbid medium; said beam  
7 penetrating the thin section during a first range of times  
8 corresponding to beam propagation depth into the thin section;

9 a streak tube, having a cathode for receiving reflected  
10 light back, approximately along the illumination-propagation  
11 direction, from the thin section of turbid medium during a  
12 second range of times corresponding to total propagation  
13 distances into and out from the thin section approximately  
14 along the illumination-propagation direction; said streak tube  
15 also having an anode end, and comprising:

16  
17 first electronic means for forming at the anode end  
18 of the streak tube successive thin-strip-shaped electron-  
19 ic-image segments of the light successively received on  
20 the cathode from the illuminated turbid-medium thin sec-  
21 tion, at particular times corresponding to the particular  
22 total propagation distances for particular penetration  
23 depths, and  
24

25 second electronic means for distributing the succes-  
26 sive thin-strip-shaped electronic image segments, along a  
27 direction generally perpendicular to a long dimension of  
28 the images, across the anode end of the streak tube in  
29 accordance with said second range of times corresponding  
30 to total propagation distances into and out from the thin  
31 section of turbid medium, to form a composite electronic  
32 image of the turbid-medium thin section as a function of  
33 propagation depth.

19.

1 ~~37~~ The imaging system of claim ~~36~~<sup>18</sup>, further comprising:  
2 electrooptical means for receiving the electronic-image  
3 segments and in response producing corresponding optical-image  
4 segments to display a composite optical image.

SUB 84

1 38. The system of claim 37, further comprising:

2 means for displacing the beam-projecting means and streak  
3 tube together, along a direction generally perpendicular to a  
4 long dimension of the thin section of turbid medium, while  
5 sequentially operating the beam-projecting means to project a  
6 sequence of beam pulses to illuminate successive thin sec-  
7 tions, and generate a corresponding sequence of composite  
8 electronic and optical images; and

9 means for visually displaying the sequence of said  
10 optical images to show a motion picture that emulates visual  
11 perceptions of travel through the successive thin sections of  
12 turbid medium.

1 39. The system of claim 37, further comprising:

2 means for displacing the beam-projecting means and streak  
3 tube together, along a direction generally perpendicular to  
4 the illumination-propagation direction, while sequentially  
5 operating the beam-projecting means to project a sequence of  
6 beam pulses to illuminate successive thin sections and gener-  
7 ate a corresponding sequence of composite electronic and  
8 optical images; and

9 means for visually displaying the sequence of said  
10 optical images to show a motion picture that emulates visual  
11 perceptions of travel through the successive thin sections.

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SUBB6

1 40. The system of claim 39, further comprising:  
2 means for roughly compensating for geometrical effects  
3 that systematically vary the intensity of reflected light,  
4 along the long dimension of the thin section of turbid medium.

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41 41. The imaging system of claim 36, wherein:  
2 the beam-projecting means comprise means for projecting  
3 the pulsed beam with very short duration, and substantially in  
4 the shape of a line that is extended perpendicular to the  
5 illumination-propagation direction, to selectively illuminate  
6 a succession of substantially line-shaped thin shallow volumes  
7 of the turbid <sup>ocean-volume</sup> ~~medium~~ thin section at successive propagation  
8 depths respectively; and  
9 said streak-tube cathode receives the reflected light  
10 successively from said succession of substantially line-shaped  
11 thin shallow volumes, respectively.

1 42. The system of claim 41, further comprising:

2 an optical focal element interposed in front of the  
3 streak-tube cathode, for imaging onto the cathode light re-  
4 flected from the turbid-medium thin section; and wherein

5 the cathode receives the reflected light in the form of a  
6 succession of thin-strip-shaped images of the succession of  
7 illuminated substantially line-shaped thin shallow turbid-  
8 medium volumes, respectively; and

9 the first electronic means form the successive thin-  
10 strip-shaped electronic-image segments, at the anode end of  
11 the streak tube, as electronic images of the succession of  
12 thin-strip-shaped cathode images.

1 43. The system of claim 42, further comprising:

2 means for roughly compensating for geometrical effects  
3 that systematically vary the intensity of reflected light,  
4 along a long dimension of the thin-strip-shaped images on the  
5 cathode.

1 44. The system of claim 41, wherein:

2 the beam-projecting means comprise means for projecting  
3 the pulsed beam to penetrate the turbid-medium thin section to  
4 reach a substantially light-impenetrable surface beyond the  
5 thin section;

6 said surface having a surface relief that comprises  
7 plural levels of said light-impenetrable surface, successively  
8 encountered by each beam pulse in propagating along the  
9 illumination-propagation direction; and

10 the second electronic means form said composite image  
11 including a profile of the light-impenetrable surface relief;

12 wherein said extremely short duration facilitates spatial  
13 resolution of relatively shallow features within said surface  
14 relief.

15  
45. The system of claim 41, wherein:

2        said illumination-propagation direction is substantially  
3        in a radially diverging pattern, diverging radially from the  
4        beam-projecting means;

5        each substantially line-shaped beam pulse has the shape  
6        of a circular segment, with the beam-projecting means substan-  
7        tially at the center; and

8        the cathode receives the reflected light back approxi-  
9        mately along the same radial pattern, but converging.

1       46. The system of claim 36, further comprising:

2        a field-limiting slit for isolating, within the light  
3        imaged onto the cathode, said back-reflected light approxi-  
4        mately along the illumination-propagation direction;

5        thereby substantially excluding light reflected along  
6        other directions.

1       47. The system of claim 36, further comprising:

2        means for enhancing the composite image at the anode end  
3        of the streak tube.



27. 18  
48. The system of claim 36, wherein:

1 the first electronic means operate over a range of times  
2 beginning substantially with receipt of reflection from the  
3 surface of the turbid <sup>ocean volume</sup> ~~medium~~ thin section; and  
4

5 the second electronic means operate over substantially  
6 the same range of times to form the composite image extending  
7 from a line that represents the surface of the turbid <sup>ocean volume</sup> ~~medium~~  
8 thin section toward lines representing the interior of the  
9 turbid <sup>ocean volume</sup> ~~medium~~.

28. 18  
49. The system of claim 36, wherein:

1 the first electronic means operate over a range of times  
2 ending substantially with receipt of optical information by  
3 the system indicating that a limit of penetration depth has  
4 been reached; and  
5

6 the second electronic means operate over substantially  
7 the same range of times to form the composite image from lines  
8 representing the interior of the turbid <sup>ocean volume</sup> ~~medium~~ thin section to  
9 a line representing the limit of propagation depth.

29  
50. The system of claim ~~36~~<sup>18</sup>, wherein:

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B  
3B  
2 the beam-projecting means comprise means for projecting  
3 the pulsed beam to penetrate the turbid ~~medium~~<sup>ocean volume</sup> thin section to  
4 reach a substantially light-impenetrable surface beyond the  
5 turbid ~~medium~~<sup>ocean volume</sup> thin section;

6 said surface having a surface relief that comprises  
7 plural levels of said light-impenetrable surface, successively  
8 encountered by the pulsed beam in propagating along the  
9 illumination-propagation direction; and

10 the second electronic means form said composite image  
11 including a profile of the light-impenetrable surface relief.

1 ~~51. The system of claim 50, wherein:~~

2 ~~the streak tube cathode successively receives reflected~~  
3 ~~light back, approximately along the illumination-propagation~~  
4 ~~direction, from the plural levels of the light-impenetrable~~  
5 ~~surface, respectively.~~

1 52. The system of claim 36, wherein:

2 the first electronic means operate over a range of times  
3 beginning substantially with receipt of reflection from the  
4 surface of the turbid-medium thin section, and ending substan-  
5 tially with receipt of optical information by the system  
6 indicating that a limit of penetration depth has been reached;  
7 and

8 the second electronic means operate over substantially  
9 the same range of times, so that the composite image extends  
10 from a line representing the surface of the turbid-medium thin  
11 section to a line representing the limit of propagation depth.

1 53. The system of claim 52, wherein:

2 the limit of penetration depth is a substantially light-  
3 impenetrable surface beyond the turbid-medium thin section.

1 54. The system of claim 36, further comprising:

2 means for enhancing the composite electronic image at the  
3 anode end of the streak tube;

4 said enhancing means comprising electronic means for  
5 amplifying electron flow, within the streak tube, that creates  
6 the composite image.

30.

18

55. The system of claim 36, further comprising:

means for roughly compensating for geometrical effects

that systematically vary the intensity of reflected light

along the long dimension of the thin section of turbid medium;

ocean volume  
medium

said roughly-compensating means comprising optical means

for generally reversing the relative intensities of (1) the

light projected near ends of the thin-fan-shaped beam with

respect to (2) the light projected near the center of the

thin-fan-shaped beam.

SUBC7

56. The system of claim 36, further comprising:

means for displacing the beam-projecting means and streak tube together, along a direction generally perpendicular to a long dimension of the thin section of turbid <sup>ocean volume</sup> ~~medium~~, while sequentially operating the beam-projecting means to project a sequence of beam pulses to illuminate successive thin sections of turbid <sup>ocean volume</sup> ~~medium~~, and generate a corresponding sequence of composite electronic images; and

means for using the sequence of composite electronic images as an emulation of video data recorded in travel through the successive thin sections of turbid <sup>ocean volume</sup> ~~medium~~; said using means comprising means selected from the group consisting of:

means for using the sequence of composite electronic images to display a video sequence that emulates visual perceptions of travel through the successive thin sections of turbid <sup>ocean volume</sup> ~~medium~~, and

means for recording the sequence of composite electronic images to be used later in displaying such a video sequence.

1 57. The imaging system of claim 36, further comprising:  
2 electron-sensitive, spatially discriminating means for  
3 receiving the successive thin-strip-shaped electronic-image  
4 segments and in response generating a flow of photons to  
5 produce corresponding optical-image segments.

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1 58. The system of claim 57, further comprising:  
2 means for enhancing the composite optical image;  
3 said enhancing means comprising electrooptical means for  
4 amplifying said flow of photons generated by the electron-  
5 sensitive means.

1 59. The imaging system of claim 58, wherein:  
2 the electron-sensitive means comprise a phosphor screen  
3 that displays the composite optical image.

1 60. The imaging system of claim 59, wherein:  
2 the phosphor screen is disposed across the anode end of  
3 the streak tube.

1 61. The imaging system of claim 59, wherein:

2 the electrooptical means comprise video means for record-  
3 ing and reproducing the composite optical image displayed by  
4 the screen.

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18  
36. 62. The imaging system of claim 36, further comprising:

2 a detector array for receiving the composite electronic  
3 image and in response producing a corresponding data array;  
4 and

5 data-array utilization means selected from the group  
6 consisting of:

7  
8 a video display for receiving the data array  
9 and in response displaying a corresponding optical  
10 image, and

11  
12 means for recording the data array to be dis-  
13 played later.

1 63. The imaging system of claim 36, wherein:  
2 the beam-projecting means comprise a laser.

SUB B2

1 64. An imaging system for forming an image of a thin sec-  
2 tion of a turbid medium with objects therein, said system  
3 comprising:

4 means for projecting a pulsed thin-fan-shaped beam to  
5 selectively illuminate a thin section of such turbid medium;

6 a streak-tube cathode for receiving reflected light back,  
7 approximately along the illumination-propagation direction,  
8 from the thin section of turbid medium;

9 means for focusing the reflected light onto the streak-  
10 tube cathode substantially directly;

11 said focusing means comprising (1) no image slicer, and  
12 (2) no pixel-encoding fiber bundle, and (3) no other image-  
13 remapping device; and

14 streak-tube means, responsive to the focused reflected  
15 light, for forming therefrom a corresponding composite elec-  
16 tronic image of the turbid-medium thin section as a function  
17 of propagation depth.

39.  
1 ~~65.~~ The imaging system of claim ~~64~~, further comprising:

2 electrooptical means for receiving the composite elec-  
3 tronic image and in response producing corresponding optical-  
4 image segments to display a composite optical image.



SUBC 10

1 66. The system of claim 65, further comprising:

2 means for displacing the beam-projecting means and  
3 streak-tube means together, along a direction generally  
4 perpendicular to a long dimension of the thin section of  
5 <sup>ocean-volume</sup> turbid ~~medium~~, while sequentially operating the beam-  
6 projecting means to project a sequence of beam pulses to  
7 illuminate successive thin sections of turbid <sup>ocean-volume</sup> ~~medium~~, and  
8 generate a corresponding sequence of composite electronic  
9 images;

10 whereby the electrooptical means produce a corresponding  
11 sequence of composite optical images; and

12 means for displaying the sequence of composite optical  
13 images to show a motion picture that emulates visual percep-  
14 tions of travel through the turbid <sup>ocean-volume</sup> ~~medium~~ thin section.

SUB B97

1 67. A method of imaging a turbid medium with objects therein,  
2 said method comprising the steps of:

3 projecting a pulsed thin-fan-shaped beam to selectively  
4 illuminate, along an illumination-propagation direction, a  
5 thin section of such turbid medium;

A5  
Cont 6 then at a substantially common location with the project-  
7 ing step, receiving reflected light back, approximately along  
8 the illumination-propagation direction, from the thin section  
9 of turbid medium;

10 forming successive thin-strip-shaped image segments of  
11 the reflected light successively received along approximately  
12 the illumination-propagation direction;

13 distributing the successive thin-strip-shaped image seg-  
14 ments, along a direction generally perpendicular to a long  
15 dimension of the images;

16 said distributing of the image segments being in accor-  
17 dance with elapsed time after the beam-projecting step so that  
18 each thin-strip-shaped image segment is displaced from a  
19 common baseline position substantially in proportion to total  
20 propagation distance and time into and out from the medium, to  
21 form a composite image of the turbid-medium thin section as a  
22 function of propagation depth;

23 after the projecting and receiving steps, shifting said  
24 common location in a direction substantially at right angles

25 to both (1) a long dimension of the thin-fan-shaped beam and  
26 (2) the illumination-propagation direction;

27 repeating all of the above steps multiple times, with at  
28 least the projecting, receiving and shifting steps in the  
29 indicated order, to form multiple composite images of progres-  
30 sively encountered turbid-medium thin sections as a function  
31 of propagation depth.

42.

1 ~~68~~ The method of claim ~~67~~, further comprising:

2 displaying the sequence of composite images in human-  
3 visible form, as a motion picture that emulates visual per-  
4 ceptions of travel through the turbid <sup>ocean-volume</sup> ~~medium~~.

43.

1 ~~69~~ The method of claim ~~67~~, wherein:

2 the image-segment forming step is at least in part an  
3 electronic step, and the successive thin-strip-shaped image  
4 segments of the reflected light are electronic image segments;  
5 and

6 the distributing step is at least in part an electronic  
7 step.

44.  
70. The method of claim ~~69~~<sup>43</sup>, wherein:

the successive thin-strip-shaped image segments are distributed by deflection of an electron beam forming said electronic images.

45.  
71. The method of claim ~~67~~<sup>41</sup>, particularly for use with substantially thin-strip-shaped light-sensitive photoelectronic means, and wherein the image-segment forming step comprises:

optically focusing said received light, reflected from the thin-fan-shaped beam, onto the substantially thin-strip-shaped light-sensitive photoelectronic means so that intensity variations along the reflection of the thin-fan-shaped beam, within said focused light, are arrayed along the photoelectronic means; and

response of the photoelectronic means to said received reflected light by generation of a corresponding substantially unidimensional electronic signal array, wherein electronic signal variations along the array correspond to said intensity variations of the focused light along the photoelectronic means;

whereby said successive thin-strip-shaped image segments take the form of successive substantially unidimensional electronic signal arrays.

46.  
72. The method of claim 71, wherein:

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1 the distributing step comprises applying the successive  
2 substantially unidimensional electronic signal arrays to  
3 control successive optical-image lines of a two-dimensional  
4 display device, to construct said composite image of the  
5 turbid-<sup>ocean-volume</sup>medium thin section as a function of propagation depth.  
6

IN THE DISCLOSURE:

Please change the title of the application to read thus:  
--UNDERWATER IMAGING IN REAL TIME, USING SUBSTANTIALLY DIRECT  
DEPTH-TO-DISPLAY-HEIGHT LIDAR STREAK MAPPING-- .

In the Abstract of the application at line 12, please  
change "optic" to: --optical element-- .

88P  
5/22/95  
~~On page 19 at line 13, please change equation (1) to read  
in its entirety as set forth below. (Please note that for  
clarity funny quotes have been omitted from this expression.)~~

$$\text{E} = \pi B (n.a.)^2 A \quad (1)$$

88P  
5/22/95  
On the same page at line 15, change the minus sign "-" to  
a multiplication symbol "----" .